Coupling Passive Acoustic Techniques to Survey Spawning Fish Habitats

Combinando Técnicas de Acústica Pasiva para Estudiar Hábitats de Agregaciones de Desoves de Peces

Couplage des Techniques Acoustiques Passives pour Enquêter sur les Habitats des Poissons Reproducteurs

MICHELLE T. SCHÄRER[1]*, EVAN TUOHY[2], and RICHARD S. APPELDOORN[2]
[1]*P.O. Box 1442, Boquerón, Puerto Rico 00622 USA. *michelle.scharer@upr.edu*
[2]*Department of Marine Science, University of Puerto Rico,*
P.O. Box 9000, Mayagüez, Puerto Rico 00681 USA.
evan.tuohy@upr.edu, richard.appeldoorn@upr.edu

EXTENDED ABSTRACT

Essential fish habitat is an important designation used to protect habitats that are necessary for the completion of life cycles for marine species. Measuring the areas of submerged habitat used by reef fishes for reproduction is critical for any ecosystem-based management approach in fisheries management and marine conservation. Surveys and mark recapture methods are commonly used to achieve this goal by providing empirical evidence of habitat use patterns. We propose that these investigations could be augmented and, in some cases, substituted for species that produce sound during reproductive behaviors, with non-invasive passive acoustic techniques. Given the difficulties and costs of conducting *in-situ* observations and mark-recapture studies, this alternative was useful for some grouper species.

The increasing use of bioacoustics is particularly valuable for species that are known to produce sounds during communications associated with different behaviors, including reproduction, in Doradidae, Bagridae, Pimelodidae, Batrachoididae, Gadidae, Sciaenidae, Holocentridae, Pomacentridae, Scorpaenidae, Carapidae, and Epinephelidae (Zelick et al. 1999, Kaatz 2002, Ladich and Myberg 2006, Amorim et al. 2015). Reproductive behaviors accompanied by acoustic signals of some Caribbean groupers that have been described (Mann et al. 2010, Schärer et al. 2012a, 2012b, 2014) are produced consistently when fish migrate to, and aggregate at specific areas for spawning (Bertucci et al. 2015, Myrberg and Lugli 2006, Rowell et al. 2012, 2015). The detection of fish within specific habitats that demonstrate temporal patterns that match those known for species that aggregate to spawn is an effective way to gauge habitat use.

Nassau grouper (*Epinephelus striatus*) are one of many grouper species that produce courtship associated sounds (CAS) during reproductive behaviors at spawning sites (Schärer et al. 2012b). During the time fish are aggregated for reproduction they are highly vulnerable to directed and incidental catch, as well as other natural (predation) and anthropogenic (noise) impacts. Understanding their temporal patterns of habitat use is critical for their population maintenance, given that this species has been designated as threatened with extinction in the US Caribbean (NOAA 2016). To generate information necessary to designate critical habitats essential for the conservation of Nassau grouper, passive acoustic data were coupled with the acoustic detections of fish tagged internally at a known spawning site.

Bajo de Sico is a submerged seamount off western Puerto Rico in which most reef species are banned to fishing seasonally (October to the end of March). At this site, ambient sounds have been consistently recorded during the spawning seasons of groupers in the region, from December through May (Schärer et al. 2012b). The combination of passive acoustic hydrophone recorders coupled with acoustic tag receivers allowed for the verification of the presence/absence of tagged fish at times when species-specific CAS were detected. This approach provides for a higher resolution of detections, which permits description of (i) hourly movements throughout the detection array and (ii) the duration of the behaviors associated with reproduction, namely the courtship and competition for mates (Colin 1992). During two years (2015 - 2016), passive acoustic recordings were made simultaneously with a study of habitat use on the seamount based on 29 adult Nassau grouper internally tagged with acoustic tags (Tuohy et al. 2015). Acoustic tag receivers were distributed on the shallow areas of the top of the seamount extending approximately 2.2 Km^2. The hydrophone recorders of ambient sounds (DSG) were deployed throughout a reduced area comprising approximately 20,000 m^2 near the area where fish congregate to conduct reproductive behaviors that precede spawning. Sounds were recorded with a high time interval (20 seconds every 5 minutes) and from each file the sound levels (dB re 1μPa) were calculated for the frequency range of Nassau grouper CAS. Twelve files recorded hourly were then pooled by day to compare with acoustic tag detections at the main courtship arena.

Sound levels fluctuated in the same temporal pattern as the acoustic tag detections throughout the spawning seasons monitored. Prior to the beginning of the spawning peak time, no CAS were detected and only 6 of the 29 tags were detected, suggesting these individuals are residents in a home range that overlaps the main courtship arena where spawning takes place later in the year. As the full moon of January 2015 approached, a minor increase was observed in both tag detections and sound levels; however, this increased peak was approximately half of the magnitude of subsequent peaks after the full moons of February and March. In April of 2015 another peak was observed in both tag detections and sound production, however the magnitude of sound levels was less than the January peak (Figure 1). May was also very low in sound and tag detections, yet detectable. This pattern was repeated in 2016.

This analysis provides an estimate of the proportional abundance of Nassau grouper at the spawning area over time during the peak reproductive times, when the majority of fish were present and the majority of CAS were detected. Coupled detections of acoustic tags and CAS provided a detailed view of the timing in which critical habitats were being used during the spawning aggregation. The combination of passive acoustic monitoring techniques and acoustic tagging of spawning grouper at this site provides evidence of temporal and spatial patterns of diel habitat use during the reproductive season.

Some of the advantages of the passive acoustic technique include a low cost of deployment and recovery of the instruments, high sampling frequency, night-time sampling, sampling during adverse weather conditions, and a record of the soundscape, which may include the sounds of other animals, vessels and the noise generated by environmental or anthropogenic sources. These benefits make passive acoustics a strong tool to consider in gathering residency data given the ephemeral nature of critical habitat use by some species and the logistical constraints of in-situ surveys or tagging. Some disadvantages include the technical requirements of signal recognition in large datasets, environmental heterogeneity of coral reef environments affecting the probability of detection, not being able to verify why fish are not being detected, inability to infer density of fishes from sound levels, variability in species specific sounds, and masking of target sounds by other sounds including those from anthropogenic sources. All of these considerations can be incorporated into the monitoring of critical habitats for species designated as threatened with extinction or for the study of essential fish habitat for species that are to be harvested sustainably, albeit in areas where they do not aggregate to spawn.

KEYWORDS: Nassau grouper, acoustic telemetry, passive acoustic monitoring, spawning aggregations, Puerto Rico

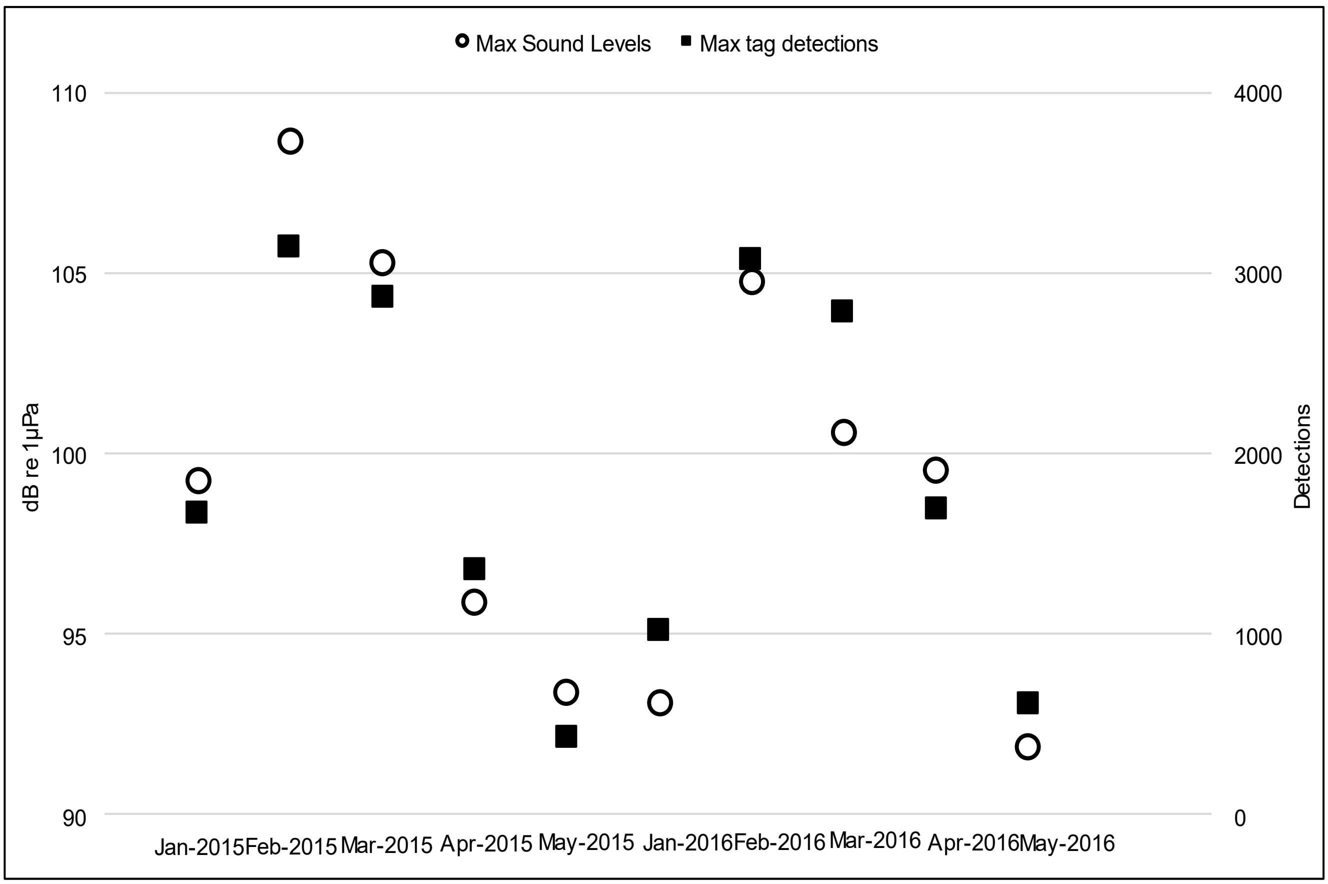

Figure 1. Combination of passive acoustic maximum sound levels and maximum detections of tagged Nassau grouper (*Epinephelus striatus*) per month during the spawning seasons of 2015 and 2016.

LITERATURE CITED

Amorim, M.C.P., R.O. Vasconcelos, and P.J. Fonseca. 2015. Fish sounds and mate choice. Pages 1–33 in: F. Ladich (Ed.) *Sound Communication in Fishes*. New York, New York USA.

Bertucci, F., P. Lejeune, J. Payrot, and E. Parmentier. 2015. Sound production by dusky grouper *Epinephelus marginatus* at spawning aggregation sites. *Journal of Fish Biology* **87**:400-421.

Colin, P.L. 1992. Reproduction of the Nassau grouper, *Epinephelus striatus* (Pisces, Serranidae) and its relationship to environmental conditions. *Environmental Biology of Fishes* **34**:357-377.

Kaatz, I.M. 2002. Multiple sound-producing mechanisms in teleost fishes and hypotheses regarding their behavioral significance. *Bioacoustics* **12**:230-233.

Ladich, F. and A.A. Myrberg. 2006. Agonistic behavior and acoustic communication. Pages 121-148 in: F. Ladich, S.P Collin, P. Moller, and B.G. Kapoor, (Eds.) *Communication in Fishes*. Enfield, New Hampshire USA.

Mann, D., J. Locascio, M. Schärer, M. Nemeth, and R. Appeldoorn. 2010. Sound production by red hind *Epinephelus guttatus* in spatially segregated spawning aggregations. *Aquatic Biology* **10**:149-154.

Myrberg, A.A. and M. Lugli. 2006. Reproductive behavior and acoustical interactions. Pages 149–176 in: F. Ladich, S.P Collin, P. Moller, and B.G. Kapoor, (Eds.) *Communication in Fishes*. Enfield, New Hampshire USA.

NOAA. 2016. Endangered and Threatened Wildlife and Plants: Final Listing Determination on the Proposal to List the Nassau Grouper as Threatened Under the Endangered Species Act. 50 CFR Part 223, *Federal Register* **81**(125):42268-42285.

Rowell, T.J., R.S. Nemeth, M.T. Schärer, and R.S. Appeldoorn. 2015. Fish sound production and acoustic telemetry reveal behaviors and spatial patterns associated with spawning aggregations of two Caribbean groupers. *Marine Ecology Progress Series* **518**:239-254.

Rowell, T.J., M.T. Schärer, R.S. Appeldoorn, M.I. Nemeth, D.A. Mann, and J.A. Rivera. 2012. Sound production as an indicator of red hind density at a spawning aggregation. *Marine Ecology Progress Series* **462**:241-250.

Schärer, MT, M.I. Nemeth, D.A. Mann, J.V. Locascio, R.S. Appeldoorn and T.J. Rowell. 2012a. Sound production and reproductive behavior of Yellowfin grouper, *Mycteroperca venenosa* (Serranidae) at a spawning aggregation. *Copeia* **2012**:135-144.

Schärer, M.T., T.J. Rowell, M.I. Nemeth, and R.S. Appeldoorn. 2012b. Sound production associated with reproductive behavior of Nassau grouper *Epinephelus striatus* at spawning aggregations. *Endangered Species Research* **19**:29-38.

Schärer, M.T., M.I. Nemeth, T.J. Rowell, and R.S. Appeldoorn. 2014. Sounds associated with the reproductive behavior of the black grouper (*Mycteroperca bonaci*). *Marine Biology* **161**:141-147.

Tuohy, E., M.I. Nemeth, I. Bejarano, M.T. Schärer, and R.S. Appeldoorn. 2015. *In Situ* tagging of Nassau Grouper *Epinephelus striatus* using closed-circuit rebreathers at a spawning aggregation in Puerto Rico. *Marine Technology Science Journal* **49**:115-123.

Zelick, R., D.A. Mann, and A.N. Popper. 1999. Acoustic communication in fishes and frogs. Pages 363–411 in: R.R. Fay and A.N. Popper (Eds.) *Comparative Hearing: Fish and Amphibians.* New York, New York USA.